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# Temperature changes and their impact on soil moisture in winter and spring

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ABSTRACT

Interannual variability of hydrometeorological variables may indirectly influence soil moisture conditions in winter and early spring seasons. The interactions between temperature changes and soil moisture are studied by an application of statistical analyzes of minimum temperature ($T_{min}$), consecutive days with temperatures exceeding the 0$^o$C threshold value and a number of melting pulses in winter season. Additionally shifts in timing of season arrivals and length of periods without precipitation are analysed. Mann-Kendall test is applied for the trend analysis. Studies have shown significant changes in thermal characteristics in the winter season over the past 69 years, which may affect the moisture conditions in the Vistula River basin.

## 1. Introduction

The phenomenon of drought constitute a complicated research problem. Droughts are the result of the seasonal interplay of precipitation, soil moisture, and snow processes. The propagation from meteorological to hydrological drought strictly depends on precedent moisture conditions. Due to a climate change, thermal conditions in the cold half of the year are changing rapidly, twice as fast as in the summer season (IPCC, 2013). In Poland in recent years dryer and milder winters are observed. It is disadvantageous for agriculture as it cause a decrease of soil moisture in spring due to decrease of water storage in the soil. Therefore in the present study an emphasis is placed on the analysis of thermal conditions in the cold half of the year, which generate changes in the retention processes. Hydrometeorological characteristics were used to indirectly assess soil moisture conditions, especially its retention potential during snow melt periods. Changing pattern of melting pulses and temporal shifts in the start dates of growing season are very important from the point of view of surface runoff delay and soil moisture retention at a crucial moment for plant growth. The decreased water retention in spring may strongly interact with thermic conditions of the summer season. A number of studies indicate that extreme meteorological conditions, including drought and hot extreme, become more frequent. In Poland in recent decade there is an evidence of drought signals becoming more frequent and wide-spread (Somorowska, 2016; Tokarczyk and Szalińska, 2014, Tomczyk and Szyga-Pluta, 2018). The aim of this study is to analyse interannual variability of hydrometeorological indices that indirectly characterize soil moisture conditions in winter and early spring season.

## 2. Materials and methods

Hydrometeorological characteristics indirectly characterizing soil moisture conditions in winter and early spring season were applied. The analyzed indicators included: maximum minimum temperature – max$T_{min}$, number of days with $T_{mean} > 0^oC$ – $NDT_{mean}$, number of days with $T_{min} > 0^oC$ – $NDT_{min}$, maximum length of consecutive days with $T_{mean} > 0^oC$ – $maxCDT_{mean}$, maximum length of consecutive days with $T_{min} > 0^oC$ – $maxCDT_{min}$, number of melting pulses based on differences between daily maximum and minimum temperature – $NMP_{max-min}$, number of melting pulses based on a day-to-day differences in daily mean temperature $NMP_{mean}$, maximum length of consecutive days without precipitation (P < 0 mm) – $CDP_{zero}$. Standardized precipitation index( SPI) and the standardized precipitation evapotranspiration index (SPEI) were used as indirect soil moisture indicators. Threshold level (TL) method was applied to identify consecutive days without precipitation, winter season days with temperature exceeding the 0$^o$C and number of melting pulses. Mann-Kendall test was used for trend analysis of selected indices. The analysis was performed using daily temperature and precipitation data from 22 meteorological stations located in the Vistula River basin for the period 1951-2019.

## 3. Results

Figure 1 presents the significance test results for changes in the maxima of annual minimum temperatures for all the stations examined. For most of the stations the positive trend is statistically significant at the 0.05 level. In Figure 1 the panels present respectively January, February and March, starting from the left to right.

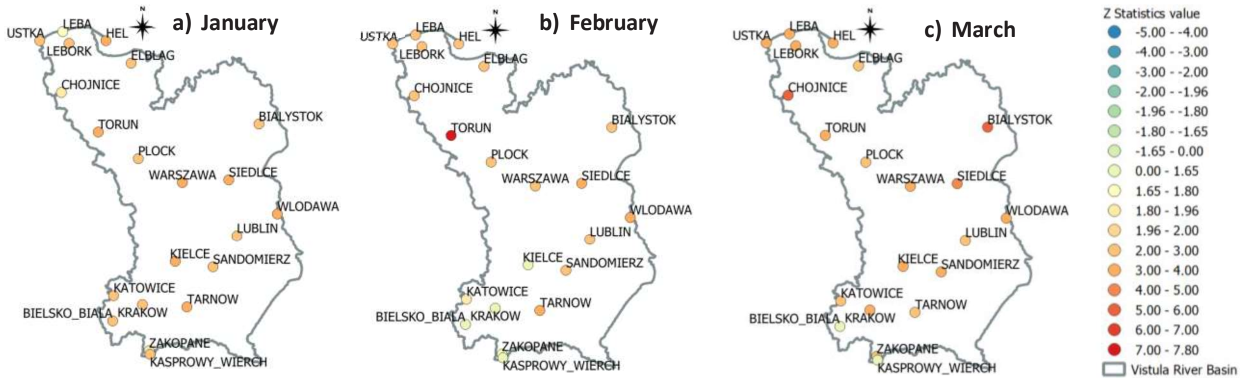


**Fig. 1.** Significance test results for changes in the maxima of annual minimum temperatures for the Vistula basin for the period 1951-2019 for January (left panel), February (middle panel) and March (right panel). The colours in the legend show the significance of the changes. The statistical value Z <-1.96 indicates a statistically significant decreasing trend at the significance level α=0.05 and Z > 1.96 a statistically significant increasing trend at the significance level α=0.05.

Figure 2 presents the degree of changes in the maxima of annual minimum temperatures per decade described by the Sen's slope value. The panels correspond to January, February and March, as in Figure 1. The range of changes varies between 0.01 to 0.6 $^{o}$C per decade.

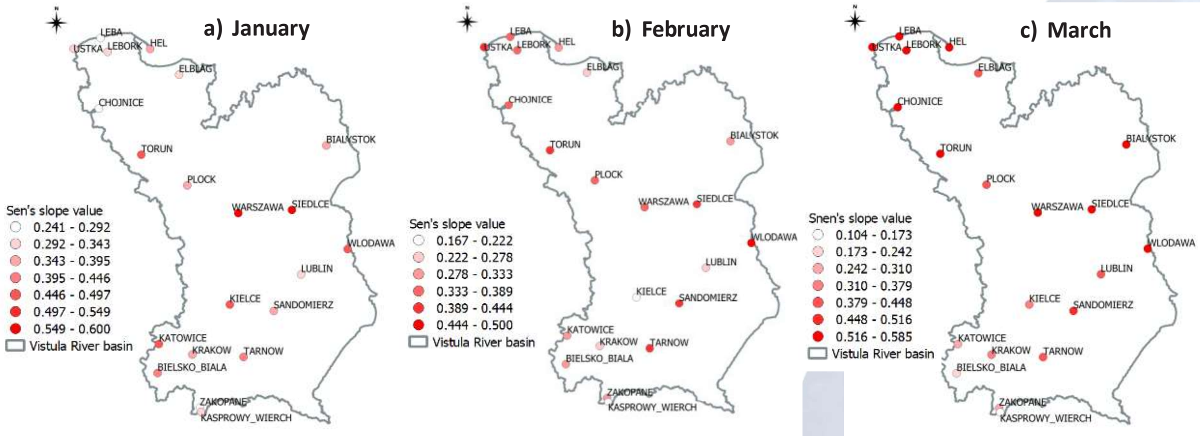


**Fig. 2.** Sen's slope values for the significance test results (Fig. 1) for changes in the maxima of annual minimum temperatures for the Vistula basin for the period 1951-2019 for January (left panel), February (middle panel) and March (right panel).

Analysis of interannual changes of hydrometeorological characteristics examined showed a decrease of a number of pulses on average by two pulses per decade, an increase of number of days with positive temperatures in the winter season on average by 2.5 days per decade. These preliminary results indicate that significant thermal changes in winter season occur. Our study confirms significant shifts in spring start dates and changes in the length of the seasons. These thermal changes coincide with the changes in precipitation patterns leading to drought risks.

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